Patent Application

for

Gamma Calibration

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Cross-Reference to Related Applications

[0001] This application claims the benefit under 35 U.S.C. Section 120 of the following co-pending and commonly-assigned U.S. utility patent application(s), which is/are incorporated by reference herein:

[0002] United States Patent Application Serial No. 09/675,917, entitled "Gamma Calibration", by Laurence Cloutier, filed on September 29, 2000, Attorney Docket No. 30566.121-US-01.

Field of the Invention

[0003] The present invention relates to satisfying a plurality of gamma requirements for displaying images on a monitor, and in particular relates to processing images for a computer monitor such that images previewed on the monitor have the same appearance as they would have after being transferred to film and viewed in a theater.

Introduction to the Invention

[0004] Image transducers convert between patterns of light intensities and patterns of electrical charge. The relationship between light intensity at a point on an image and its corresponding electrical signal, expressed as a voltage, is non-linear. In a television camera, for example, a small increase in light intensity at high levels will result in a smaller change in voltage than the same increase in intensity at low light levels. A television monitor containing a cathode ray tube has the opposite characteristic: an increase in electron gun voltage has an exponential relationship with the intensity of light emitted by phosphors at the screen.

[0005] Each such transducer's characteristic may be defined by a response curve, representing the transfer function of the transducer. For many transducers these response curves can be expressed mathematically as an

exponent applied to a numerical argument representing the transducer's input normalised to a range of zero to one. This exponent has come to be known in the image processing industry as gamma.

[0006] Historically, television cameras and monitors were designed to have compatible gamma characteristics. In early systems, the camera had a gamma of 0.4545, and the monitor had a gamma of about 2.8. This results in an overall gamma of $2.8 \times 0.4545 = 1.27$.

[0007] The overall gamma of an image processing system is the exponent which broadly defines the relationship between the intensity of light reaching the viewer's eye and the intensity of light that entered the camera. In a theoretically perfect system, an overall gamma value of 1.0 would reproduce image intensities exactly as they would be seen by the naked eye. However, it has been shown that images viewed artificially benefit from an overall gamma value of greater than one.

[0008] For television, the overall gamma value is usually 1.27, but overall gamma is used to characterise many types of image processing system, including film. For cinematographic film, the required overall gamma is 1.5. When images destined for film are being edited digitally it is necessary to preview the results of editing on a monitor prior to their conversion back to film. Unless compensation steps are taken, images will appear differently on the monitor than on the resulting film. This is mostly due to the difference in gamma characteristics between cinematographic film and CRT monitors.

[0009] In a typical digital editing environment, a film scanner digitizes film images that are subsequently transferred to a digital frame store. The digital frame store comprises an array of hard disk drives. A computer system accesses and manipulates the images in the frame store in real time. The resulting image data is supplied to a film recorder, which then transfers the images back onto film. In order for the correct effects and edit decisions to be made during manipulation of the image data, it is necessary to ensure that

images viewed on a computer monitor appear as they will look in the resulting film.

Summary of the Invention

[0010] It is an aim of the present invention to provide an improved method of modifying image data for display on a monitor, so that images displayed on the monitor are consistent with gamma requirements for film.

[0011] The present invention provides apparatus for processing image data, comprising instruction storage means, central processing means and graphical processing means. The graphical processing means is arranged to receive image data and display resulting images on a color monitor. The graphical processing means includes look-up means for transforming the gamma format of the image data supplied to it. The color monitor requires a first gamma transformation to satisfy calibration requirement and the image data requires the second gamma transformation to satisfy a compensation requirement. Instruction storage means includes instructions for the central processing means to perform processing steps, that comprise combining the first and second transformations to define transformation data in the look-up means and supplying images to the look-up means such that images displayed on the monitor are transformed in response to the second gamma transformation but not said first gamma transformation.

Brief Description of the Drawings

[0012] *Figure 1* illustrates apparatus and steps performed while editing images originating on film or video that are intended for eventual viewing as film images in a theater, including a film camera, a video camera, a monitor, an image processing system and a film recorder;

[0013] *Figure* 2 details the image processing system shown in *Figure 1*, including a computer;

[0014] *Figure 3* details components of the computer shown in *Figure 2*, including a central processing unit, a main memory, a graphics card and a CDROM drive;

[0015] *Figure 4* details contents of the main memory shown in *Figure 3* during image processing, including digital effects and editing instructions and look-up tables;

[0016] *Figure 5* details components of the graphics card shown in *Figure 3*;

[0017] *Figure 6* summarises steps performed by the digital effects and editing instructions shown in *Figure 4*, including a step of defining gamma correction for a monitor;

[0018] *Figure 7* illustrates gamma characteristics of several items of apparatus shown in *Figure 1*;

[0019] *Figure 8* summarises the step of defining gamma correction for a monitor, shown in *Figure 6*, in accordance with the present invention, including defining a monitor calibration requirement, a user-defined compensation requirement, an adjustment requirement and a combining process;

[0020] *Figure 9* details characteristics of the requirements shown in *Figure 8*;

[0021] *Figure 10* illustrates a graphical user interface presented to a user when performing the step of defining gamma calibration for a monitor shown in *Figure 6*;

[0022] *Figure 11* summarises graphical user interface operations performed in response to user interactions with the interface shown in *Figure 10*;

[0023] *Figure 12* details operations performed while defining the monitor calibration requirement shown in *Figure 8*;

[0024] *Figure 13* details source code for instructions executed by the central processing unit shown in *Figure 3* when performing the combining process shown in *Figure 8*; and

[0025] *Figure 14* details source code for instructions executed by the central processing unit shown in *Figure 3* when downloading data generated in

accordance with *Figure 13* to the graphics card shown in *Figure 3*.

Detailed Description

[0026] A sequence of image processing events is summarised in *Figure 1*. A camera **101** is used to record a scene onto cinematographic film. The resulting film is converted into digital form by a film scanner **102**, that has an output in the form of digitally encoded magnetic tapes **103**. An alternative source of image data is a digital video camera **104**, that directly generates digital data onto digital video tape **105**. A digital editing and effects processing environment **106** includes facilities for modifying image data supplied in the form of digital tapes **103** and or **105**.

[0027] Typical operations carried out in the processing environment **106** include processing to apply special effects, such as a color warping, color keying etc and to perform edits. While editing and effects processing **106** is applied, the results of edit and effects processes are viewed on a video monitor **107**. Effects and edits are tried out in several variations before a preferred effect or edit point is finalised. In this way, the operator of the editing and effects processing environment **106** may create a high quality image sequence. Once a sequence has been finalised, image data is transferred to digital tapes **108**. In the event that this data is intended for film, the tapes **108** are supplied to a film recorder **109** which scans the images onto cinematographic film. The film is eventually placed in a projector **110** for projection onto a screen **111** in a theater **112**.

[0028] *Figure* 2 details equipment used to perform the editing and effects processing **106** shown in *Figure 1*. A digital tape player **201** receives digital tapes **103, 105** containing image data. This data is transferred via a Silicon Graphics Octane (TM) computer **202** to a redundant array of independent disks (RAID) **203**. Once located on the RAID **203**, image data may be manipulated efficiently and in real time by the computer **202**. An operator

controls image editing and processing operations via a stylus-operated graphics tablet **204** and a keyboard **205** that are connected to the computer **202**. A colorimeter **206**, having a similar size and appearance to a computer mouse, may be fixed to the centre of the screen of the monitor **107** during a monitor calibration procedure.

[0029] The operator interacts with and modifies image data stored on the RAID **203** until an image sequence has been finalised. At this point, final image data is transferred to tapes **108** inserted in the digital tape player **201**, for eventual transfer to the film recorder **109**.

[0030] The Silicon Graphics Octane computer **202** shown in *Figure 2* is detailed in *Figure 3*. A pair of MIPS R12000 central processing units (CPU) **301** and **302** include primary instruction and data cache memories. The two CPUs **301** and **302** communicate with secondary cache memories **303** and **304**, that are one megabyte each in capacity. The CPUs **301** and **302** communicate, via a memory controller **305**, with a switch **306** and a main memory **307**. The main memory consists of two gigabytes of dynamic RAM. The switch facilitates connectivity between several of the attached circuits. A graphics card **308** receives instructions and data from the switch **306** in order to render image data for display on the monitor **107**. A high bandwidth SCSI interface **309** provides connectivity to the digital tape recorder **201** and the RAID **203**. An input/output interface **310** facilitates connections with the graphics tablet **204**, the keyboard **205** and the colorimeter **206**. A second SCSI bridge **311** provides connectivity to an internal hard disk drive **312** and a CDROM drive **313**.

[0031] A CDROM inserted into the CDROM drive **313** may contain instructions for performing image editing and processing upon image data stored in the RAID **202**. Instructions on the CDROM may be installed on the hard disk drive **312** for subsequent use whenever the computer is switched on. Installation is facilitated by installation instructions, which may also be

supplied on the CDROM, and which define steps performed by the CPUs **301** and **302** necessary to ensure appropriate installation of the editing and processing instructions on the hard disk. Thereafter, instructions from the hard disk **312** may be loaded into main memory **307** for execution by the CPUs **301** and **302** whenever image editing and effects processing is required. In an alternative embodiment, instructions may be downloaded via a network, such as the internet.

[0032] The main memory **307** stores instructions and data necessary for the operation of the computer **202**. Contents of the main memory during execution of editing and effects processing instructions are detailed in *Figure 4*. A Silicon Graphics Irix (TM) operating system **401** provides common functionality for applications running on the computer **202**. Digital image effects, editing and processing instructions **402** are substantially based upon the Inferno (TM) system available from the present applicant. System data **403** includes data necessary for the correct functioning of the operating system **401**, A data storage area **404** provides temporary storage for image manipulation by the image processing instructions **402**. Four look-up tables (LUT) **405** to **409** are stored in main memory. Each LUT comprises two hundred and fifty-six words of data that will be used in the invention.

[0033] The graphics card shown in *Figure 3* is detailed in *Figure 5*. Processing and input output circuitry **501** co-ordinates processing of image data, and communication between its internal processors, the switch **306** and a graphics memory **502**. The graphics memory **502** is connected to the processing and input/output circuitry **501** via data and address connections **504** and **505** respectively. The graphics memory **502** includes a hardware look-up table (LUT) **506**, comprising three look-up tables, one each for red **507**, green **508** and blue **509**. Each of these look-up tables has two hundred and fifty-six words of data. Each word comprises twelve bits. The processing and input/output circuitry **501** co-ordinates data access with the look-up table

506. The LUT **506** may be initialised with data for each red green and blue component. Thereafter, image data is transformed in accordance with data contained in the red, green and blue portions of the LUT **506**.

[0034] Details of image data transformation by the LUT **506** will now be explained with reference to the red LUT **507**. This contains two hundred and fifty-six words of data. Access within the red LUT **507** is defined by a twelve bit address, which is capable of selecting any one of the **256** data locations as a source or destination of data. If the location addressed by zero contains data of value zero, location one contains value one, location two contains value two and so on, up to two hundred and fifty-six, the LUT may be considered as performing no color transformation at all. Data supplied as an address to it generates the same value as data. If, however, the data stored in the LUT deviates from this linear relationship, another transfer function can be implemented. The LUT's in graphics cards are usually implemented in dedicated hardware, and are intended to provide real time adjustments to color that are achieved more quickly by modifying the LUTs than by modifying the color value at each individual pixel in an image or series of images.

[0035] The output of each LUT **507**, **508** and **509** is multiplexed to a digital to analog circuit **510**, which generates red, green and blue analog signals that are supplied to the monitor **107**. Most of the time, addresses supplied to the LUT **506** are color values requiring transformation. However, in order to set up a transformation function in the LUT **506**, addresses are used to write specific data to locations in any or all of the red, green and blue LUTs **507** to **509**, hence the transfer of data **505** between the LUT **506** and the processing circuit **501** is bi-directional.

[0036] The creative decisions made in the editing and effects processing environment **106** rely on there being a close similarity between the images viewed on the monitor **107** and the images seen by an audience in the theater **112**. An important difference between film and video formats is in

their gamma characteristics.

[0037] The steps performed by an operator using the digital editing environment shown in *Figure 2* are summarised in *Figure 6*. A CD ROM 600 contains digital editing and effects instructions **402**. These may be installed on the hard disk drive **312**, if necessary, at step **601**. At step **602** the digital editing instructions **402** are initialised, and these are loaded into main memory **307**. At step **603** a film clip is imported by reading image data from digital tapes **103** via the tape recorder **201** onto the RAID **203**.

[0038] At step **604** the gamma correction for the monitor **107** is defined. Instructions for this process are included in the editing and effects instructions **402**.

[0039] At step **605** the clip is edited and processed using editing and effects instructions **402**. At step **606** the finished clip, comprising a finalised image sequence, is transferred to digital tapes **108**, and at step **607** the digital editing application is closed.

[0040] Gamma characteristics are illustrated in *Figure 7*. Image data generated by the video camera **104** retains its natural gamma of 0.45, as this type of data is usually displayed, without gamma compensation, on television screens having a gamma of 2.5. Thus, video data has a gamma value that must be taken into consideration when this type of data is being processed for eventual use in film. The process of shooting a scene onto negative film results in a typical gamma value of 0.6. However compensation for this may be done in the film scanner **102** when a linear output format is requested. If this is done, the film data received by the editing and effects processing system **106** has a gamma value of 1.0.

[0041] A video monitor, such as monitor **107**, has a gamma value of 2.5. Thus, the light emitted by the phosphors on a cathode ray tube is proportional to a normalised representation of the voltage supplied to the electron guns, raised to the power 2.5.

[0042] When generating a film positive, as is done in the film scanner **109**, the corresponding gamma is 3.0.

[0043] During image processing **106**, the overall gamma is affected by the chain of processes starting with the light entering the camera **101** or **104** and ending with the light emitted from the cathode ray tube's phosphors **107**. At the time of projection, however, the overall gamma is affected by the chain of processes again starting with the camera **101** or **104** but ending with the light appearing on the cinema screen **111**.

[0044] In both instances it is required that the overall gamma be the same and equal to 1.5. In order to satisfy this overall gamma requirement, images viewed on the monitor **107** must be modified by applying a gamma correction function.

[0045] Step **604** for defining gamma correction for the monitor, shown in *Figure 6*, is detailed in *Figure 8*. A monitor calibration requirement **801** is defined as data in the first look-up table LUT1 **405**, shown in *Figure 4*. A user-defined compensation requirement **802** is defined in the second look-up table LUT2 **406**. An adjustment requirement **803** is defined in a third look-up table LUT3 **407**. A combining process **804** combines requirements defined by the contents of LUT1, LUT2 and LUT3 and generates data that is temporarily stored in LUT4 **408**. This data is then supplied as configuration data for the hardware LUT **506** in the graphics card **308**. In an alternative embodiment, LUT4 is not created, and data generated as a result of combining LUT1, LUT2 and LUT3 is supplied directly to the graphics card to configure the hardware LUT **506**.

[0046] Each of LUT1, LUT2 and LUT3 comprises three LUTs, one each for red, green and blue, although this is only strictly necessary when red, green and blue characteristics differ. This is the case for the monitor calibration requirement **801**.

[0047] The monitor calibration requirement **801** compensates for

irregularities in the monitor's red, green and blue intensities. These irregularities occur as a result of component ageing and changes in ambient conditions. A characteristic is determined for each of the red, green and blue electron guns, as is shown in *Figure 9* at **901**, **902** and **903**. These requirements are determined using an automated calibration procedure that measures the intensities of light emitted by the screen phosphors of the monitor **107** under various different conditions of color and luminance. These characteristics are determined empirically and are defined in the form of compensating tables of data **901**, **902** and **903**. These tables define the red, green and blue tables of LUT1 **405**.

[0048] The user-defined compensation requirement **802** is selected from multiple predetermined compensation characteristics, selected by the user. A first table **911** has an 'S' shaped curve. This is the characteristic of an uncompensated film print, developed from an uncompensated negative. It includes characteristics of both the film camera **101** and the film recorder **109**. Thus, when a film print is scanned using the film scanner **102** and converted into digital form without any gamma compensation, the 'S' curve table **911** represents the intensity distortions that need to be introduced into a gamma-neutral system if the film look is to be simulated correctly for film that has been digitized without any gamma compensation.

[0049] If compensation for film gamma has been applied during digitization by the film scanner **102**, then the 'S' shape table must be superimposed upon a linear to logarithmic conversion table **912**. The result of this combination is a film look-up table **913**, having a distorted 'S' shape. Table **913** is then considered as the user-defined compensation characteristic. Linear format video may also be given a film look. However, because the linear video format has an inherent gamma pre-distortion, a different table **914** is used. This is combined with the 'S' table **911** to give the film look table **913** that will be used for video input.

[0050] When a logarithmic, uncompensated, digitized film input is used, the table that is combined with the 'S' table **911** is a straight line 1:1 table **915**. Combination of table **911** with any of the three input format tables **912, 913** or **914** is given by the relation:

FILM_LOOK_LUT[x] = S_CURVE_LUT[[INPUT_LUT[x]]

[0051] The value of x is varied until all table values are filled, and interpolation may be used to ensure monotonicity of the final resulting LUT **913**.

[0052] Film look is dependent upon the 'S' curve LUT **911** being appropriate to the film chemistry of the particular film stock that is being used. Since this will vary from manufacturer to manufacturer, and depending upon the laboratory where the film is developed, a custom film look LUT **916** option is provided. The contents of this LUT are copied from user-specified data from measurements of actual film characteristics. Using custom LUT **916**, it is possible to apply the invention to any type of film stock. In many applications, film look is not desirable, or the clips that are being edited and processed are destined for video, in which case an all video LUT **917** is provided. This has a neutral gamma characteristic.

[0053] The user-defined compensation characteristic **802** is given by any of the three tables **913, 916** or **917**. If the film look table **913** is being used, this will have been created by combining the 'S' shape table **911** with any one of tables **915, 912** or **914**, depending on the input format and source of the image data that is being processed.

[0054] When the table **913, 916** or **917** has been selected, the table data is copied into LUT2 as three identical red, green and blue tables. In an alternate embodiment, it is possible that the tables **911** to **915** may provide separate control over red, green and blue components, in which case selection of this

option will result in non-identical red, green and blue curves being transferred to LUT2.

[0055] The third requirement is the adjustment requirement **803**. The adjustment requirement is a table of data derived from several parameters. These parameters are the monitor gamma, usually 2.5, the overall gamma usually 1.5, the system gamma, usually 1.7, an offset value and a gain value. Monitor gamma is fixed. However, other parameters may be varied, depending upon several factors. For example, several of these settings may vary depending on the ambient lighting conditions of the room in which the monitor **107** is located. Various calibration procedures may be performed in order to ensure optimal settings for parameters such as gain and offset, so that the user of the system can be assured that the results that are being viewed on the monitor are as close as possible to those that will be seen in the intended environment, such as the theater **112**.

[0056] The combination of these parameters results in an adjustment requirement, defined as a curve in a table **921**. Data for this requirement is then copied from the table **921** into the red, green and blue tables of LUT3.

[0057] In combination, the requirements **801**, **802** and **803** determine the contents of a transformation LUT **506** which, when applied to image data, results in the display of images on the monitor having an appearance substantially in accordance with the same images when they are subsequently displayed in the theater **112**.

[0058] The monitor calibration requirement **801** may be considered as a first gamma requirement. The user-defined compensation requirement **802** may be considered as a second gamma requirement, and the first and second gamma transformations are defined in response to these requirements. These transformations are represented by tables of data **405** and **406**. The first and second transformations are combined by the combining process **804** to define the data contents of the look-up table **506** in

the graphics card **308**, so that images displayed on a monitor are transformed in response to the compensation requirement but not the monitor calibration requirement. The first gamma transformation removes unwanted transformations inherent in the monitor's electronic circuits while the second gamma transformation modifies image data to match its appearance on film even though it is being displayed on a monitor. An adjustment requirement, affected possibly by multiple parameters including system gamma, may also be included, thereby ensuring that the overall gamma of the image processing system is correct.

[0059] The user interface displayed on the monitor **107** at step **604** is illustrated in *Figure 10*. An image **1001** is displayed in the top part of the display area to show the effect of changes made during the definition of gamma correction parameters. The monitor also displays soft buttons for monitor calibration **1001**, initialization **1003** and adjustment **1004**. These enable the user to define requirements **801**, **802** and **803** respectively. A load configuration button **1005** enables the user to load previously saved configurations of the requirements **801**, **802** and **803**. A save configuration button **1006** enables the user to save the current configuration. This arrangement permits one or several users to set multiple definitions for monitor gamma correction, which may be saved or recalled when required.

[0060] A state diagram representing interaction of the user with the interface shown in *Figure 10* is shown in *Figure 11*. The desktop graphical user interface (GUI) environment receives user-interface event signals from the operating system **401** in response to user operation of the keyboard **205** or the graphics tablet **204**. The desktop environment **1101** determines the context of events received, and selects an appropriate action. A dialog for defining monitor calibration requirements **801** is initiated in response to pressing soft button **1002**. A dialog for defining user-defined requirements is initiated in response to pressing soft button **1003** and a dialog for defining

adjustment requirements is initiated in response to pressing soft button **1004**. After any of processes **801**, **802** or **803** are completed, process **804** is performed, where changes in the definition of monitor gamma correction are downloaded into the hardware LUT **506** in the graphics card. In practice, once a dialog for either of processes **802** or **803** has been initiated, the system will proceed to loop through process **802** or **803**, followed by process **804**, thereby updating the display in real time, until the user decides to commit to the changes that have been made.

[0061] As a result of pressing soft buttons **1005** or **1006**, dialogs for loading or saving the present configuration are initiated at steps **1104** and **1105** respectively. These dialogs include the selection or definition of a convenient descriptive name for a configuration. It is also possible to select individual requirements stored as part of several different configurations, and combine them to form a new configuration.

[0062] Steps performed by the computer **202** when defining monitor calibration requirements **801** are detailed in *Figure 12*. At step **1201** a message is displayed requesting the user to place the colorimeter **206** in the centre of the monitor's screen. The colorimeter **206** has a suction pad and a light sensor. The suction pad fixes the base of the colorimeter to the monitor screen, and the light sensor converts light intensities into an electrical signal. A suitable colorimeter is the X-Rite DTP-92. Detailed information is available at http://www.xrite.com. At step **1202** the first of a predetermined sequence of colors is displayed on the monitor. At step **1203** the colorimeter response is measured. The colorimeter converts the light energy arriving at its sensor into an electrical signal, which is then quantified by an analog to digital converter. The output of the analog to digital converter is supplied in a serial format to the input/output circuit **310** in the computer **202**, which then stores this measurement value temporarily. At step **1204** a question is asked as to whether another color should be displayed. If so, control is directed to step

1202 and the next color is selected. After all of the colors have been displayed, control is directed to step **1205**. At this point the data accumulated from the color measurements is analysed to determine gamma requirements expressed as correction tables for red, green and blue color components. These are then stored as red, green and blue tables in LUT1. At step **1206** the user may optionally store the calibration data in a file.

[0063] The sequence described with reference to *Figure 12* is appropriate for Silicon Graphics (TM) monitors that are used with the colorimeter **206**. However, in a different embodiment, a Barco (TM) monitor may be used, having built-in detection circuitry. When this type of monitor is used, it is possible to perform an iterative process of calibration, where the colors displayed on the monitor's screen are selected on the basis of calibration results from earlier times in the calibration cycle. In this way, it is possible to identify non-linearities in the monitor's gamma characteristic by a process of convergence. Information on Barco monitors is available from http://www.barco.com.

[0064] Source code for the combining process **804** is shown in *Figure 13*. Each LUT comprises red, green and blue tables each having **256** data locations. An output LUT is generated for each of the red, green and blue component tables in turn. Source code for downloading the resulting combined LUT **408** to the graphics hardware LUT **506** is shown in *Figure 14*. This transfer is complicated by the fact the, although the hardware LUT has only two hundred and fifty-six locations, the operating system **401** considers it as having 65536. Thus, the same data value is supplied to **256** consecutive locations in order to make certain that the hardware LUT **506** is updated correctly. On other graphics processing systems, each LUT may have one thousand and twenty-four or four thousand and ninety-six entries, and so the image processing instructions **402** may interrogate the system at start up and perform necessary arithmetic procedures to ensure that maximum accuracy

is maintained.

[0065] The source code in *Figures 13* and *14* is used to generate the instructions responsible for implementing process **804**. Process **804** is itself part of the Inferno (TM) digital effects and editing instructions **402**, although it may be supplied as a separate instruction module or as part of another application. The instructions supplied on CD ROM 600 therefore include an embodiment of the invention, as many different types of hardware system can be enabled to implement the invention when supplied with suitable instructions.

[0066] Suitable instructions may be in the form of a pre-compiled executable sequence of instructions, an encoded compressed sequence of instructions for direct installation on the hard disk **312**, or in the form of source code requiring compilation using commonly available compiler tools.

[0067] It will be understood that the methods and apparatus described herein refer to a system in which a plurality of gamma requirements, expressed in the form of data in look-up tables, are combined to form data in a single look-up table that transforms image data in real time. However, look-up tables are capable of storing arbitrarily shaped transformations. It will therefore be understood that gamma requirements referred to herein and elsewhere can include requirements that go beyond the simple gamma relationship given by y = x ^ gamma (x raised to the power of gamma). An example of this is the 'S' curve **911**, which may be considered to be a gamma characteristic for the purposes of the invention, even though the 'S' shape does not arise from a simple exponential relationship. A gamma format or gamma requirement stored in a look-up table may include an offset value, a gain value, or any requirement including a non-linear gain characteristic, optionally combined with additional characteristics for the simplification or enhancement of various aspects of an image processing system, that can be defined in the form of a look-up table.